A Cost Effective Approach to Protecting Deep Sea Coral and Sponge Ecosystems with an Application to Alaska's Aleutian Islands Region

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Abstract

There is much debate about how to protect deep sea coral and sponge ecosystems using the data currently available. The Aleutian Islands in Alaska contain some of the most abundant, diverse, and pristine deep sea coral and sponge ecosystems on Earth. From 1990 to 2002, U.S. federal fishery observer data indicates approximately 2,176,648 kg of coral and sponge bycatch occurred in the Aleutian Islands, equaling 52% of all coral and sponge bycatch in Alaska. Coral and sponge bycatch rates in the Aleutians were over 12 times the rate in the Bering Sea or Gulf of Alaska. The National Marine Fisheries Service (NMFS) estimates that 87% of coral bycatch and 91% of sponge bycatch in Alaska is caused by bottom trawling in the Bering Sea/Aleutian Islands management areas. The conservation organization Oceana developed an interdisciplinary fishery management approach to mitigating adverse impacts of fishing on deep sea coral and sponge ecosystems, which has been used by NMFS to formulate a habitat protection alternative for the Aleutian Islands that is being considered in an Environmental Impact Statement. The Oceana Approach is offered as a cost effective model for reducing the adverse effects of fishing on deep sea coral and sponge ecosystems. The approach uses observer data to identify areas of high coral and sponge bycatch rates to develop a comprehensive management policy that allows bottom trawling only in specific designated areas with high fish harvest and low habitat impacts. All areas not specified as open would be closed to bottom trawling. To prevent effort displacement, bottom trawl effort is reduced by the amount that historically occurred in areas that would become closed. The Oceana Approach also includes coral and sponge bycatch limits and a plan for comprehensive seafloor research, mapping, and monitoring. An enforcement strategy for these management measures is developed based on agency capabilities, and includes increased observer coverage, vessel monitoring systems, and electronic logbooks. This approach allows for maximum catch of target species with minimal adverse impacts on coral and sponge habitat. Successful implementation of the Oceana Approach will protect areas of high known trawl impacts to deep sea coral and sponge ecosystems and prevent trawl effort from moving into new, unexplored areas. The methodology is recommended for application to other regions and should be adjusted based on the available fishery and biological data for each region.

Introduction

Advances in technology have enabled fishermen to harvest biomass from the ocean more effectively than ever before. The world's demand for fish has created economic incentives for fishermen to build bigger boats with higher horsepower and use fishing gears that can be used in deeper and harder to reach areas, and catch high quantities of fish very quickly. Industrial bottom trawling is one such gear type that has enabled more effective harvest of fish stocks by towing large nets and cables over the seafloor. However, these hard on bottom fishing activities can alter and damage seafloor ecosystems, which may impose serious adverse impacts on the features of the ocean that make it so productive. These incidental externalities of increased harvesting ability have prompted serious concerns in the scientific and conservation communities about the effects of bottom trawling on seafloor habitat (Dayton et al. 1995; Watling and Norse 1998; NRC 2002; Roberts and Hirshfield 2003). Deep sea corals and sponges are living animals that can provide three dimensional structures that form habitat for commercial groundfish, shellfish, and other marine life (Husebo et al. 2002; Krieger and Wing 2002; Malecha et al. 2002; Heifetz 2002). They are found at depths from 30 meters to over 3000 meters (Krieger and Wing 2002). Because these long-lived filter feeders are attached to the seafloor, they may be important indicators of areas in the ocean that have consistently favorable ecological conditions worth protecting for other reasons as well.

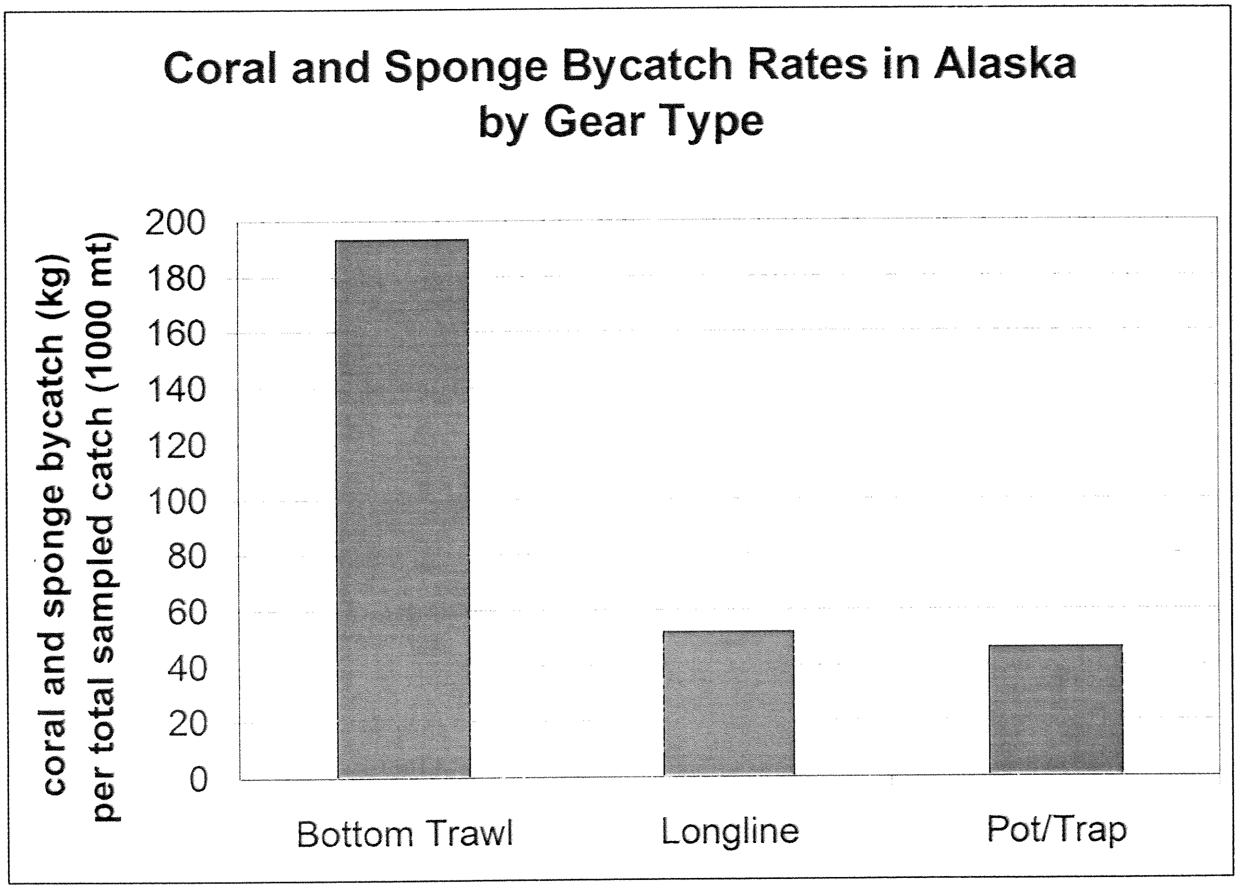


Figure 1: Bycatch rates for groundfish fishing gears in Alaska, based on data from 1990-2002. Bycatch rates are defined as the weight of reported bycatch divided by the weight of total sampled catch. These rates may not reflect actual damage to seafloor since fishing gears may not retain all corals and sponges that are impacted. Data source: NMFS 2002b.

Bottom trawling is known to decrease the quality of these habitats because they are vulnerable to damage and may take decades to centuries to recover (Cimberg et al. 1981; Freese et al. 1999; Freese 2001; Hall-Spencer et al. 2001; Krieger 2001; Andrews et al. 2002; Fossa et al. 2002; NRC 2002). Figure 1 shows that the rate of coral and sponge bycatch per metric ton of total catch is roughly four times greater for bottom trawls than for longline or pot gear types in Alaska. Because of their importance as habitat and vulnerability to human impacts, all corals and sponges have already been designated as Habitat Areas of Particular Concern (HAPCs) deserving of special protection by the National Marine Fisheries Service (NMFS) and the North Pacific Fishery Management Council (NPFMC 1998; Hogarth, Assistant Administrator for Fisheries, personal communication). HAPCs are a subset of Essential Fish Habitat (EFH) defined in U.S. law that are especially vulnerable to fishing (NMFS 2002a). Under the Magnuson-Stevens Fishery Conservation and Management Act of 1996 which governs federal fishery management in the U.S., NMFS is required to take actions that minimize the adverse impacts of fishing on EFH to the maximum extent practicable (16 U.S.C. 1863(a)(7)). However, no additional management measures have been implemented to date to protect these HAPCs.

	Coral Bycatch (kg)	Sponge Bycatch (kg)	Coral & Sponge Bycatch (kg)	Total Catch (mt)
Aleutian Islands (sampled)	201,472	1,376,074	1,577,546	1,307,144
Aleutian Islands (extrapolated)	277,985 (52% of Alaska)	1,898,663 (52% of Alaska)	2,176,648 (52% of Alaska)	1,803,556 (8% of Alaska)
All Alaska (sampled)	388,627	2,628,855	3,017,482	16,460,425
All Alaska (extrapolated)	537,063	3,632,945	4,170,008	22,747,477

Table 1: Summary of coral and sponge bycatch data for Alaska groundfish fisheries from 1990-2002 as of 9/25/02. Official total catch values are listed in the extrapolated rows in the total catch column. Sampled data represents the amounts reported by observers. Extrapolated data represents the sampled bycatch multiplied by the ratio of Official Total Catch to total sampled catch. Bycatch values are in kilograms (kg); total catch values are in metric tons (mt). "Coral Bycatch" includes bryozoans. Confidential data excluded. Data source: NMFS (2002b).

The Aleutian Islands contain some of the most abundant, diverse, and pristine deep sea coral and sponge ecosystems known on Earth. Stone (personal communication) estimates that this region easily contains over 100 species of corals and sponges. Table 1 shows observer bycatch data for corals and sponges and total catch data for the Aleutian Islands as well as Alaska-wide totals. The spatial distribution of this bycatch is depicted in Figure 2. Observer bycatch records are perhaps the best indicator of damage to deep sea coral and sponge ecosystems because they reflect the spatial heterogeneity of coral and sponge distribution and they directly measure relative removals of these habitat features from different areas. However, bycatch figures underestimate total damage because they do not count damaged corals and sponges that remain on the seafloor (trawl gear is not designed to retain corals and sponges). Total coral and sponge bycatch in the Aleutian Islands region accounts for 52% of all coral and sponge bycatch in Alaska, despite the fact that only 8% of Alaska's groundfish catch occurs in this region (NMFS 2002b). Coral and sponge bycatch rates in the Aleutian Islands were over 12 times the rate in the Bering Sea or Gulf of Alaska (NMFS 2002b). Though much damage is not reflected in reported bycatch, these numbers provide quantitative evidence of adverse impacts to habitats currently designated as HAPCs. NMFS (2002b) estimates that 87% of coral bycatch and 91% of sponge bycatch in Alaska is caused by bottom trawling. Legally, NMFS is required to take action if the adverse impacts of fishing on EFH are more than minimal and not temporary (NMFS 2002a).

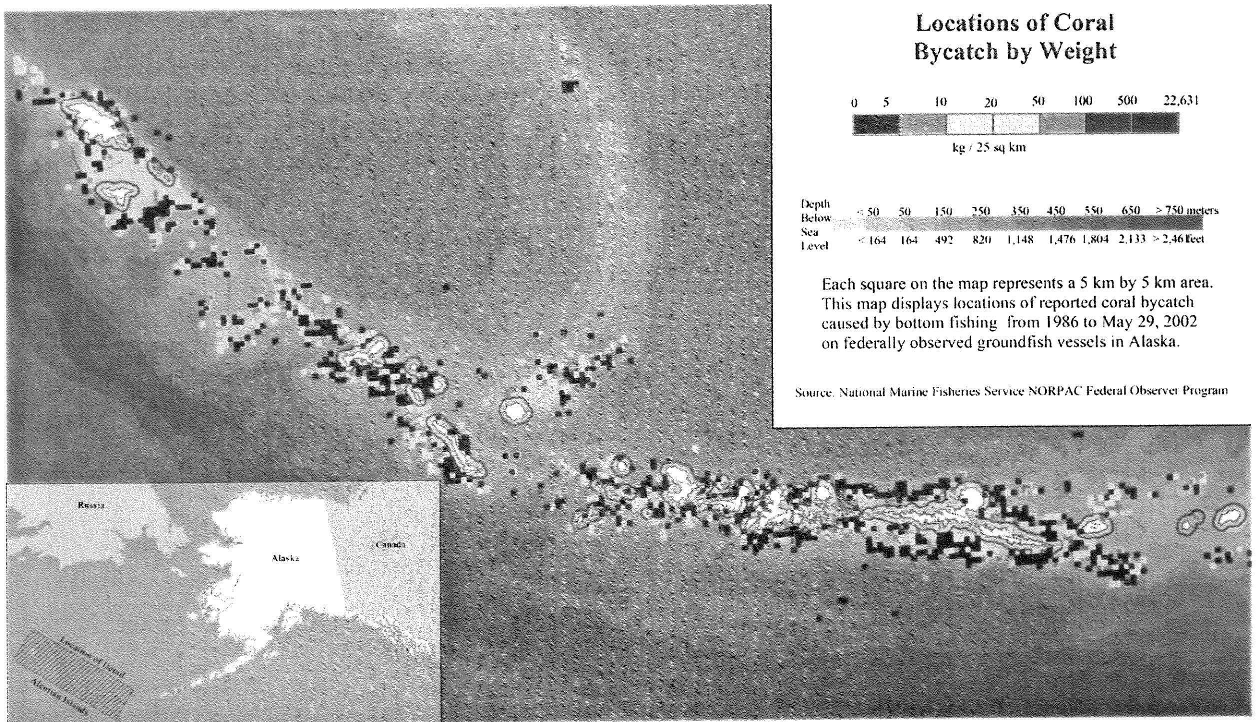


Figure 2. Coral bycatch in the Aleutian Islands reported by weight aggregated from 1986-2002. Data provided by NMFS NORPAC Federal Observer Program. Map produced by Conservation GIS Support Center, Anchorage, AK.

The three major trawl fisheries in the Aleutian Islands target Atka mackerel, Pacific cod, and rockfish (including Pacific Ocean perch, northern rockfish, and other rockfish). Estimated gross product revenue for trawl fisheries in the Aleutian Islands was $51.9 million in 2000 (J. Terry, NMFS economist, personal communication). The Aleutian Islands are split into three management areas roughly equivalent in size (Areas 541, 542, and 543) and totaling 1,004,130 km^2. In Alaska, the following species are known to associate with corals and sponges: rougheye rockfish, redbanded rockfish, shortraker rockfish, sharpchin rockfish, Pacific Ocean perch, dusky rockfish, yelloweye rockfish, northern rockfish, shortspine thornyhead, several species of flatfish, Atka mackerel, golden king crab, shrimp, Pacific cod, walleye pollock, greenling, Greenland turbot, sablefish, and various non-commercial marine species (Freese 2000; Krieger and Wing 2002; Heifetz 1999; Else et al. 2002; Heifetz 2002). Deep sea corals are known to provide protection from predators, shelter, feeding areas, spawning habitat, and breeding areas (Krieger and Wing 2002). Most corals caught in the Aleutian Islands region are gorgonian corals and hydrocorals, some of which are known to live for hundreds of years (Heifetz 2002; Andrews et al. 2002; Stone, personal communication).

It is well documented that the first pass of a trawl over sensitive habitat does far greater damage than subsequent passes (Moran and Stephenson 2000; NMFS 2004a). For this reason,

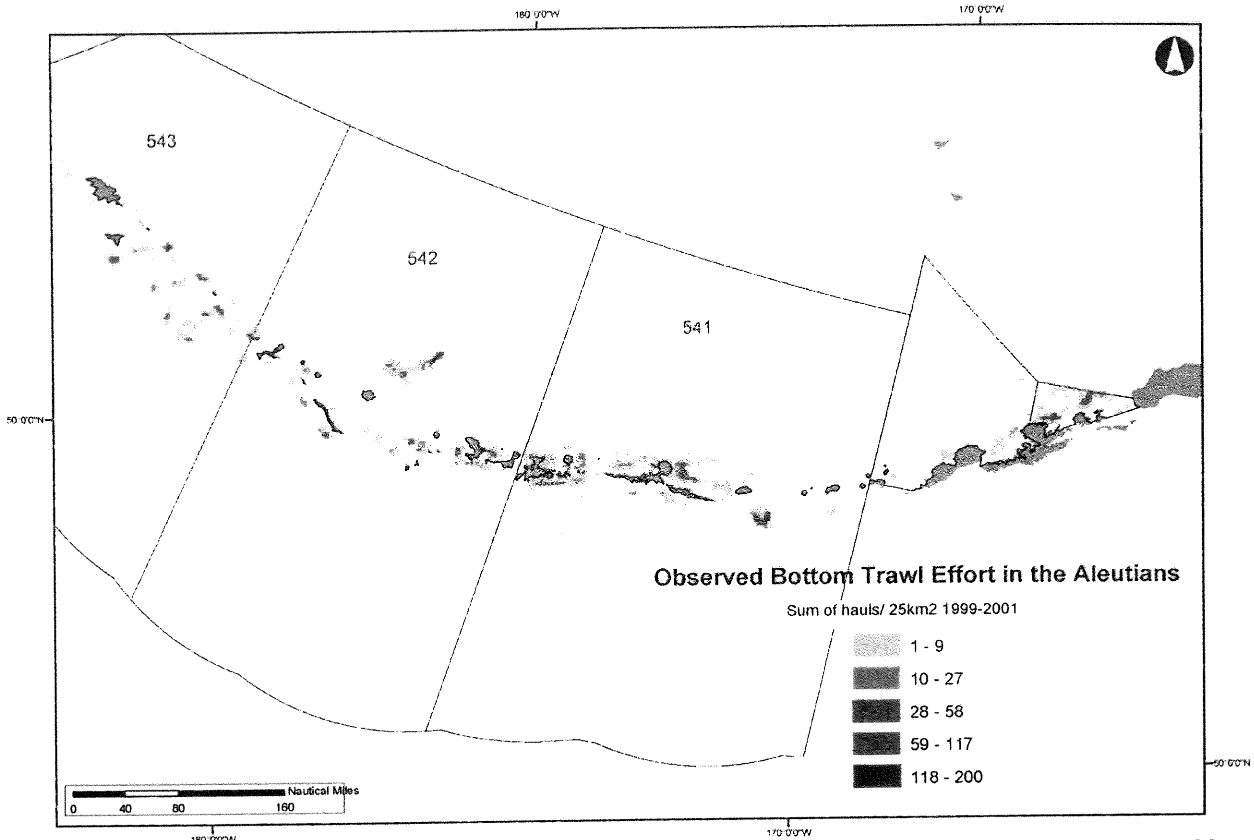


Figure 3. Observed bottom trawl effort in the Aleutian Islands management region from 1999-2001. Map provided by C. Coon, North Pacific Fishery Management Council.

The first objective of analysis is to identify areas of high and low relative economic importance to the trawl fleet. Two methods for identifying these areas are to determine the gross dollar value of fish caught annually or total number of tows over the period being analyzed. We obtained data on historic trawl effort from the Aleutian Islands to identify all grid blocks with less than a specified threshold level of fishing effort. The choice of years to use for the analysis should be broad enough to predict where the fleet is likely to be in the future and incorporate variation in fish locations over time. This increases the likelihood that the resulting policy will still work even if the fish move. Figure 3 shows an example map of trawl effort data for the Aleutian Islands region from 1999-2001 at a resolution of 5 by 5 km blocks. In areas where fishing locations are relatively static, such as continental slope areas, a shorter time series is likely encompass this variation, while on shelf habitats where fish may move over greater distances, a longer time series is more appropriate. However, it is important to note that more recent data may better reflect current fishing activity and areas where habitat interaction is greatest. Once the fishing effort time series has been selected and obtained, a threshold effort level must be selected.

This threshold specifies the level of effort in the block that is considered low enough that there will be minimal impact on the trawl fleet if the block is closed. For example, this threshold might be selected so that if closed may represent less than 1% of the historic effort, depending on what is considered minimal. Since the complete distribution of coral and sponge habitats in the Aleutian Islands and most other locations are not yet known, these areas are closed to bottom trawling in the Oceana Approach on the precautionary basis that they may contain important and sensitive habitat without representing a major loss to the trawl fleet. The idea is that some of these areas may be reopened in the future as additional research and mapping identifies areas that are not sensitive to trawl impacts (see Component 5 below). This approach will close extensive areas for fisheries that occur in specific concentrated locations, while it will close less area in fisheries that are prosecuted over a more widespread area. In the creation of Alternative 5B, NMFS kept all areas open that had greater than 10 trawl tows per grid cell over the years 1990-2001 and attempted to make these areas as linear as possible (least number of sides) (NMFS 2004b). Note that this threshold level chosen can dramatically influence the extent of closures and the associated reductions in groundfish catch. For a detailed description of the analysis and results of the spatial management components used in Alternative 5B, refer to NMFS (2004b). See Figure 4 for the version of a map of the resulting open and closed areas to bottom trawling being analyzed in Alternative 5B (NMFS 2004b).

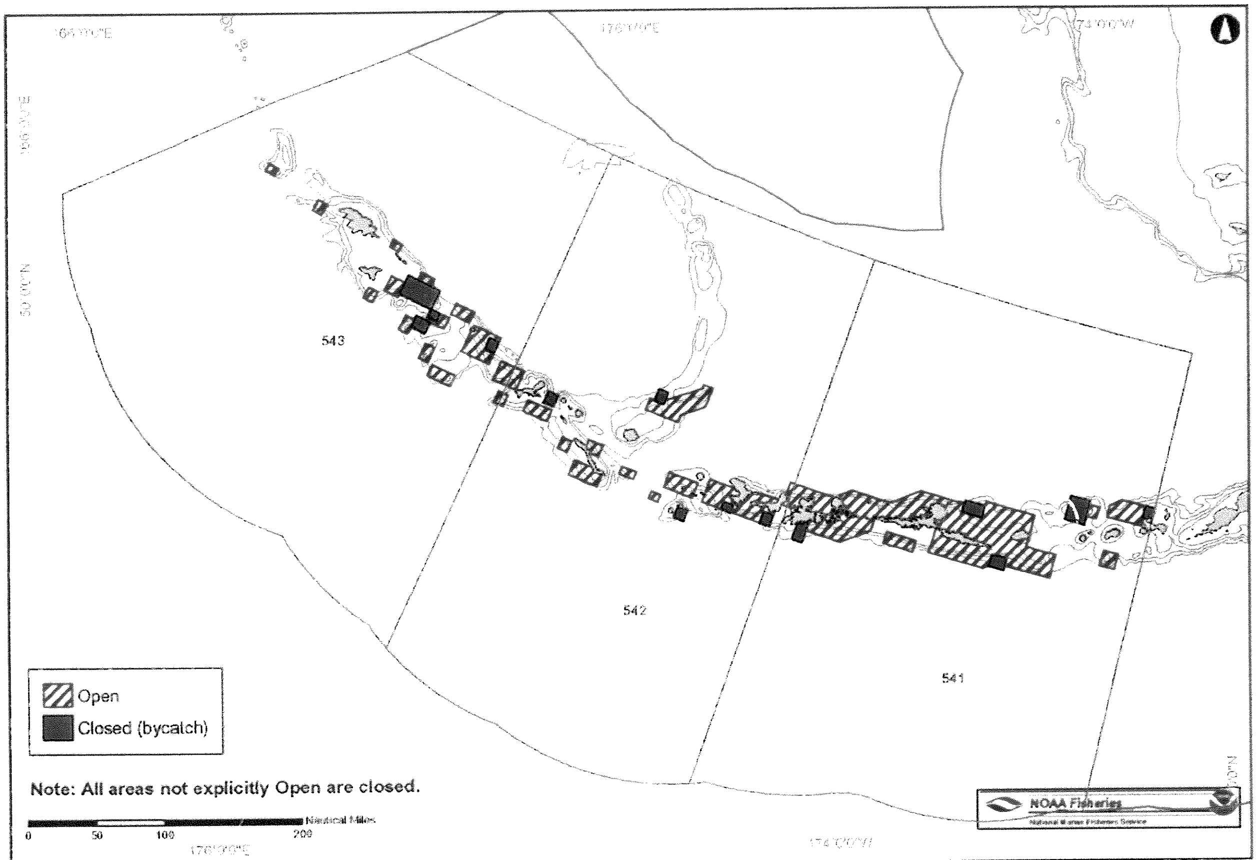


Figure. 4. Map of proposed open and closed areas to bottom trawling in the Aleutian Islands management areas in Alternative 5B, which was developed by NMFS using the Oceana Approach. Areas in white would be closed to bottom trawling on the precautionary basis that they contain less than one trawl tow per year, while potentially containing pristine deep sea coral and sponge ecosystems. Red areas would be closed to bottom trawling on the basis that the rate of coral or sponge bycatch per metric ton of groundfish catch exceeds a threshold set by NMFS. The blue striped areas are the areas that would remain open to bottom trawling on the basis that they have coral and sponge bycatch rates below the threshold set by NMFS, while incorporating most of the historic trawl effort in the region. Figure from January 2004 Draft Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, NMFS. Figure 2-50, Chapter 2.

step in an effort to protect vulnerable EFH, such as deep sea coral and sponge ecosystems in the Aleutian Islands, from fishing gears known to be destructive to structural habitat features. The basic idea behind the Oceana Approach is to protect as much deep sea coral and sponge habitat as possible at the lowest cost to the fishing industry, including locations of these habitats that have not been discovered yet. Using available data to identify areas of high coral and sponge bycatch, Oceana developed a comprehensive management policy for deep sea coral and sponge protection. The Oceana Approach is a methodology for developing a comprehensive suite of management measures that reduce adverse impacts to EFH while maintaining vibrant fisheries. The five components of the Oceana Approach are:

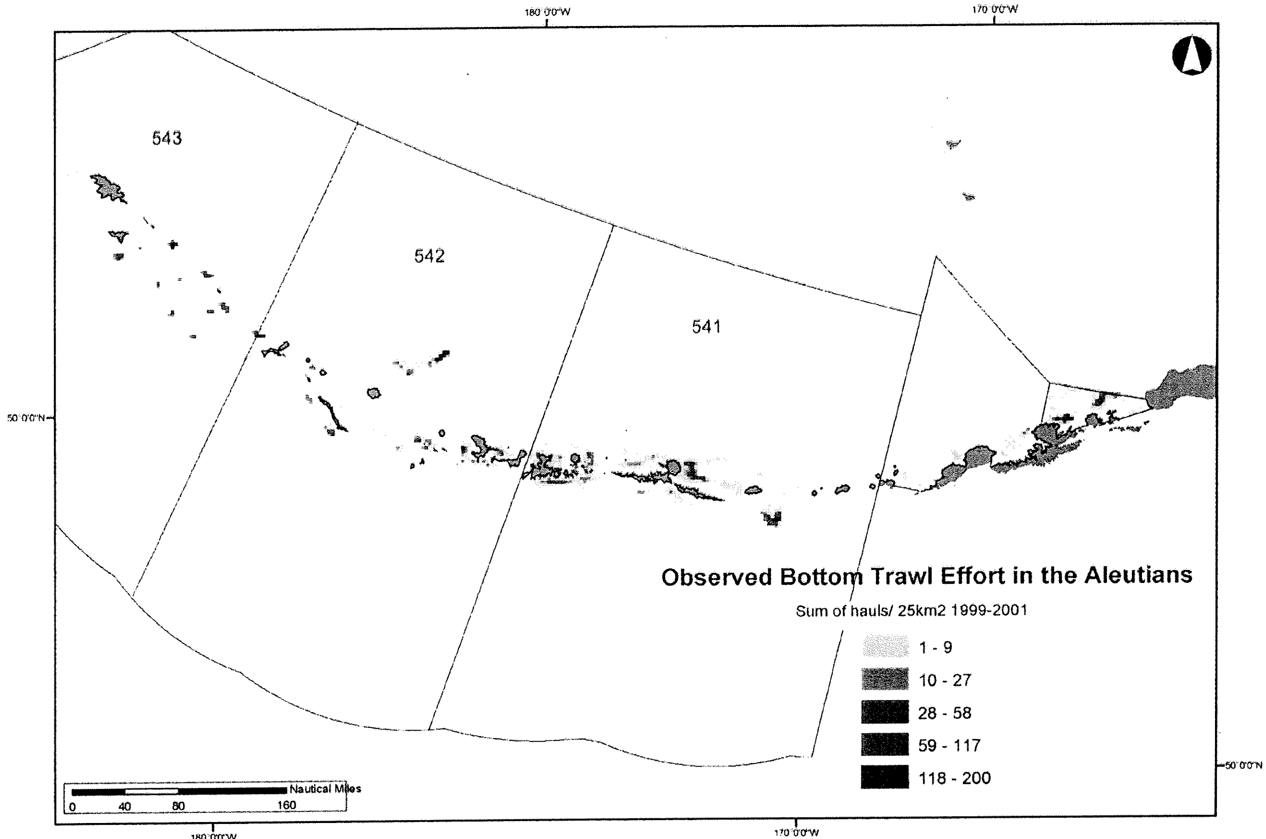
1. Designated open areas to bottom trawling;
2. Trawl effort reduction to prevent increased trawl effort in remaining open areas;
3. Coral and sponge bycatch limits;
4. Additional monitoring and enforcement requirements including vessel monitoring systems (VMS), increased observer coverage, and electronic logbooks; and
5. A comprehensive research and mapping program to inform adaptive management efforts.

Detailed descriptions and methodologies of each policy component can be found below. While Oceana developed the concept for this approach, the details contained in the methodology used to formulate Alternative 5B were developed by NMFS (2004b) as noted.

1. Designated open areas to bottom trawling

The objectives of the spatial management components of the Oceana Approach are to mitigate adverse impacts on EFH from fishing by permitting destructive fishing practices only in designated open areas with high historic target species catch where bottom contact will do the least damage to habitat.

Identifying the potential capabilities of enforcement agencies are an essential first step in the process of considering the options for spatial management. If enforcement capabilities are strong and can be done at small spatial scales, it is possible to design management measures that reflect the resolution of spatial heterogeneity of seafloor habitats. However, if enforcement cannot be done at small spatial scales, it is necessary to design open and closed areas to different fishing gears with larger grid cells. There is a tradeoff in this policy choice. Enforcement of a complex system of small-scale open and closed areas may be very expensive, but may be better able to protect sensitive areas without major impacts on fishing opportunities. However, enforcement of broad-scale open and closed areas is easier and less costly, but removes many potential opportunities to protect sensitive habitat without closing major fishing grounds. We considered these costs and benefits and took into account the specific ecological and enforcement situation in the Aleutian Islands. Ultimately, the resolution of the spatial components of Alternative 5B were selected based on advice from the US Coast Guard, which recommended a Latitude/Longitude grid based on 3 minutes of latitude by 6 minutes of longitude (NPFMC 2003). This aligns with and subdivides existing ½ by 1 degree Alaska Department of Fish & Game statistical areas in the geo-reference system familiar to the fishing fleets, and is roughly equivalent to a 5 by 5 km block. This resolution is a compromise between cost of enforcement and the ability to capitalize on the spatial heterogeneity of seafloor habitat features.



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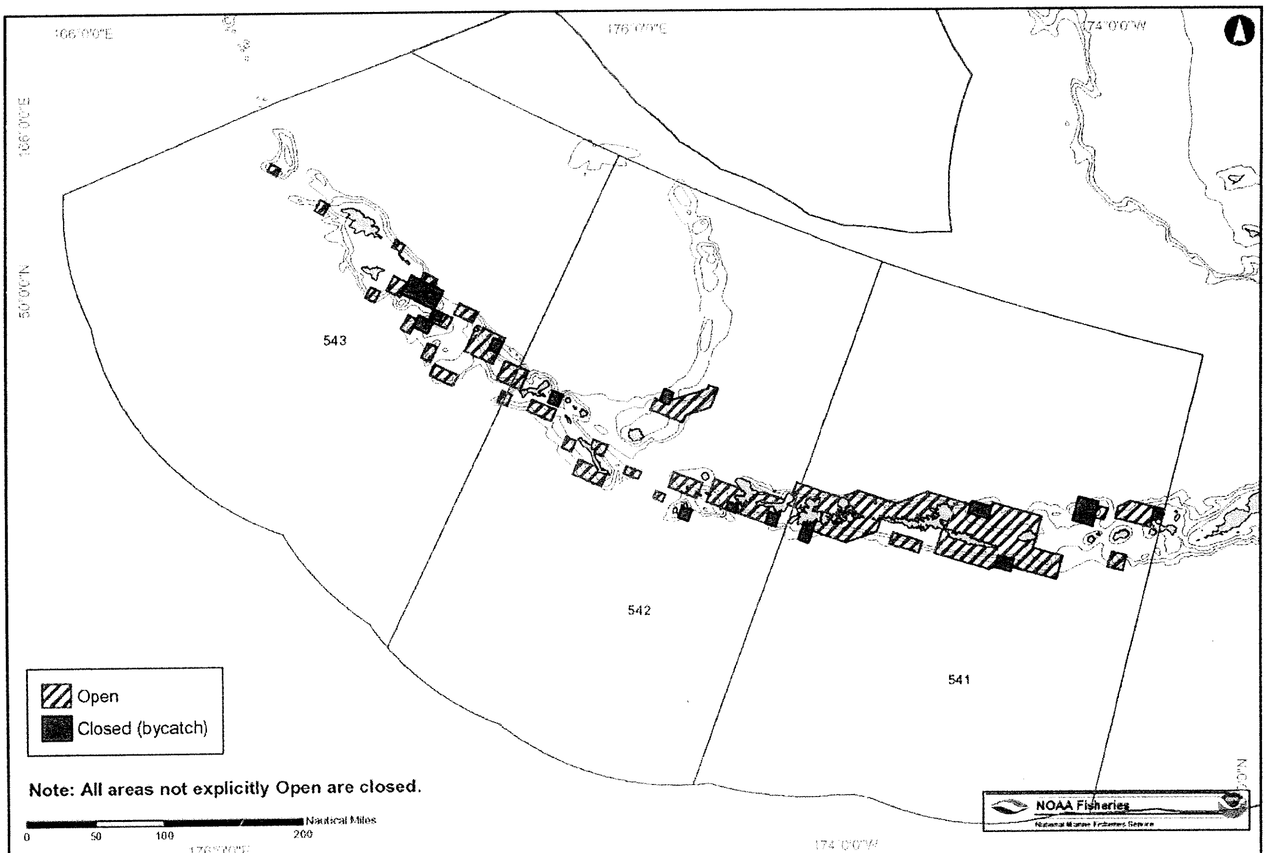

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Careful examination of the differences in bycatch rates allows an informed selection of area closures that will provides the greatest mitigation of coral and sponge bycatch with the lowest impacts on trawl catch. To accomplish this objective, we developed two indices of habitat impact rates for each block that remains open. The first was the ratio of observed coral bycatch to observed total groundfish catch from 1990-2001. The second was the ratio of observed sponge bycatch to observed total groundfish catch from 1990-2001. These ratios represent a way to measure how much impact to EFH is caused per economic benefit gained by fishing. NMFS (2004b) used natural breaks in the data to determine a threshold value for each of the two indices. Note that the method employed by NMFS may be considered arbitrary since a desired level of bycatch reduction was not selected as a basis for the threshold. Ideally, threshold values should be selected based on a thorough examination of the costs and benefits associated with different threshold values. Blocks with an impact rate above the threshold for either index become closed to bottom trawling under this approach to ensure that bycatch reduction is cost effective. These closures are considered to be the areas where the adverse impacts of bottom trawling on EFH are truly mitigated. These areas are represented as the solid red areas in Figure 4. Note that the threshold level chosen can dramatically influence the extent of closures and the associated reductions in groundfish catch. The selection of this threshold value should reflect the extent to which mitigation is warranted as well as different economic costs associated with different potential threshold values. The essence of this approach is that for any specific level of bycatch reduction desired, this approach minimizes the necessary reduction in groundfish catch.

All remaining grid blocks (those that contained more than a minimum level of historic fishing effort and were below the threshold value for the coral and sponge impact indices) remain open to bottom trawling. These areas are represented by the striped blue areas in Figure 4. It is important to note that the open areas encompass areas where some coral and sponge bycatch has occurred. Ultimately, catching targeted species without contacting these habitats is the only way to protect the remaining deep sea coral and sponge ecosystems. The coral and sponge bycatch limits described below provide a mechanism to protect corals and sponges in remaining open areas. All existing closures and management measures remain in effect and should not be altered by this methodology.

2. Effort reduction

It is well established that area closures to protect habitat must be paired with effort reduction to offset the effects of displaced effort into the areas that remain open (NRC 2002). This objective can be accomplished in several ways, such as reducing the Total Allowable Catch (TAC) allocated to the bottom trawl fleet and/or by reallocating a percentage of the bottom trawl quota to less destructive gear types. Due to the controversial nature of the latter option, we recommended reducing bottom trawl effort in the Aleutian Islands through reductions in Total Allowable Catch (TAC) equal to the proportion of total catch that occurred in areas that would become closed to bottom trawling. For a detailed description of the analysis and results of the TAC reductions used in Alternative 5B, refer to NMFS (2004b). In summary, observer data from 1998-2002 were queried to estimate the percent of bottom trawl target species catch taken from areas that would be closed to bottom trawling under Alternative 5B. For each trawl fishery in the Aleutian Islands, trawl allocation of TACs was reduced proportionally to the historic catch that was caught in areas that would become closed.

This was straightforward for the Atka mackerel and rockfish fisheries, which have TACs specifically allocated in the Aleutian Islands. However, for Pacific cod, the TAC is currently allocated for the Bering Sea and Aleutian Islands areas combined. For this reason, we recommended splitting the TAC into two separate allocations (one for Bering Sea management areas and one for the Aleutian Islands management areas) and implementing the TAC reduction in the Aleutian Islands only. To meet the objective of preventing increased trawl effort in areas that remain open, TAC reductions are necessary only in regions where closures encompass historic fishing effort. Therefore, for TAC reductions to be cost effective, TACs must be allocated at the same regional scale to which the Oceana Approach is applied.

3. Coral and sponge bycatch limits

Currently there are no limits on the bycatch of corals and sponges anywhere in North America. As of May 2002, observer bycatch records from Alaska documented 535 instances since 1990 where an observer reported bycatch of over one metric ton of corals or sponges from a single trawl tow (J. Heifetz pers. comm. 2002). Since there are no bycatch limits or penalties for this bycatch, there is currently little economic incentive to avoid this unreasonably high bycatch particularly if the catch per unit effort of target species is relatively high. Though coral and sponge bycatch limits may appear to continue destruction of habitat, we offer this tool as one component of the first step in a comprehensive strategy to reduce and eventually eliminate damage to deep sea coral and sponge ecosystems while maintaining fisheries. The three main objectives of coral and sponge bycatch limits are to:

I. Create an incentive for trawlers to avoid setting their nets in coral and sponge habitat;
II. Ensure that the bycatch mitigated through area closures does not simply shift to areas that remain open; and
III. Provide a mechanism for future habitat protection and controls on habitat impacts by fishery managers through further reductions in bycatch limits in remaining open areas.

Essentially, bycatch limits set an incidental catch allowance while fishermen pursue commercial target species. In Alaska, groundfish fishery management already uses bycatch limits for other valuable species such as halibut, salmon, and crabs. Therefore, this management component of the Oceana Approach is merely an extension of a management tool already in place. In general, bycatch limits can be applied at a fleetwide, sector, co-operative, or individual vessel basis, and result in in-season and/or post-season consequences depending on observer coverage and enforcement capabilities.

Without estimates of the total biomass of corals and sponges or the amount of actual damage reflected in observed bycatch, it may be necessary to establish the limits based on historical bycatch data. We assumed that the bycatch that occurred in areas that would become closed (red areas in Figure 4) would be mitigated by the closures. Therefore, we recommend that only bycatch that historically occurred in remaining open areas should be used to determine initial bycatch limits.

For a detailed account of the development and results of the coral and sponge bycatch limits developed by NMFS in Alternative 5B, see NMFS (2004b). In the development of Alternative 5B, NMFS determined the limits by counting all historic coral and sponge bycatch, which results in substantially higher limits than if they were determined solely from areas that remain open (NMFS 2004b). Observed bycatch numbers were expanded relative to the proportion of observed to unobserved hauls to account for unobserved bycatch. Bycatch limits were set at or near the upper end of the observed annual bycatch levels. In some cases, the bycatch limits were reduced if there appeared to be outliers, defined as an annual bycatch estimate over 2 metric tons that was more than twice the amount estimated for any of the other years examined (NMFS 2004b).

One of the most important components of a successful bycatch limit strategy for corals and sponges is determining appropriate consequences for exceeding the cap, or incentives to keep bycatch below the cap. We considered in-season area or fishery closures, further TAC reductions in subsequent fishing seasons, and/or fines on individual vessels. Consequences applied at an individual vessel level may require 100% observer coverage and be more difficult to enforce, but ensure individual accountability. Conversely, fleetwide or sectorwide consequences may not provide proper incentives. NMFS (2004b) analyzed Alternative 5B by applying the bycatch limits by fishery and management area, using in-season closures of management areas to trawl fisheries that exceed the bycatch limit for either corals or sponges.

One potential unintended consequence of coral and sponge bycatch caps is that they may create an incentive for gear modifications that retain less bycatch without reducing habitat impacts (e.g., increased roller sizes that crush corals rather than catch them in trawl nets). For this reason, it is necessary to impose gear restrictions that prevent these types of modifications and consider gear conversion to off-bottom fishing. In simmary, the application of bycatch limits should be tailored to the particular circumstances of each fishery.

4. Monitoring and enforcement

Obtaining data on interactions with corals and sponges is essential to designing effective management measures, evaluating those measures, and improving the system over time. We recommend increasing observer coverage to the extent practicable, particularly for fisheries with high gear interactions with habitat. Increased observer coverage also has wide ranging benefits for overall fisheries and ecosystem-based management, particularly because it provides more statistical power in catch and bycatch estimates so managers have a better idea of what is actually happening in the water. Current requirements for observer coverage are based on vessel size, where 100% is required for vessels over 125 feet, 30% is required for vessels 60-125 feet, and 0% is required for vessels less than 60 feet (in addition, some fisheries are required to carry two observers due to Steller sea lion protection measures, which is considered 200% coverage). In Alternative 5B, observer coverage is increased to at least 100% for all trawl fisheries. Because it may be more costly for smaller vessels to carry observers, some compensation to vessels affected by this management measure should be considered.

Vessel monitoring systems (VMS) are a new technology that tracks the location and speed of fishing vessels over time. Requiring this technology for fishing fleets that interact with habitat serves two purposes. First, it allows another mechanism for enforcing open and closed areas by displaying the real time locations of vessels and whether the vessels have deployed their gear based on their speed. Second, it enables fishery managers to observe the precise tow locations fishermen are using. Combined with observer coverage, these data can show which tows are most successful for catching target species and the average level of coral and sponge bycatch associated with each tow. These data will also be invaluable for the adaptive management component described below.

Electronic logbooks can be used to augment observer and VMS data. It allows fishing captains to display the activities and catch associated with each location in real time, allowing more accurate monitoring and enforcement. This technology also provides data with greater spatial resolution, so managers can see more detailed trawl tow paths.

Use of these three management tools are key components of a comprehensive approach to habitat management and the benefits of their implementation are widespread to all components of fishery and oceans management. Strong monitoring and enforcement capabilities are crucial to the success of all other components of the Oceana Approach.

5. Research, seafloor mapping, and adaptive management

Research and mapping play an integral role in the Oceana Approach and provide a mechanism for the management measures to become more cost effective over time. It is imperative that we invest in research and mapping if we are to maintain and restore the health of ocean ecosystems. Several specific information-gathering objectives will increase the efficacy of the Oceana Approach in each application. Seafloor mapping that identifies living substrate habitat types is critical. This type of mapping may be done with sidescan sonar and multibeam scanning (see several other papers in this volume). Combined with ground-truthing activities such as submersible or remotely operated vehicle dives, this technology can reveal areas on the seafloor that may warrant additional protections as well as areas where bottom trawling may not have destructive impacts.

Examining habitat-specific gear impacts and potential gear modifications to mitigate these impacts will provide cost-effective solutions to the problem of habitat destruction. Understanding the impacts, severity, and effectiveness of various gear types may identify preferred gear types for each fishery and habitat type. Though the Oceana Approach is focused on reducing the impacts of bottom trawling on coral and sponge ecosystems, the principles can also be applied to other gear types if they are found to be destructive to seafloor habitat. Research may also inform decisions regarding the level of mitigation necessary for applying the Oceana Approach to other gear types in the future.

Research should also explore the community ecology of coral and sponge habitats, particularly the production functions between these biogenic habitat features and commercial fish species. Once the relationship between the productive capacity of commercial fisheries and the quality and quantity of vulnerable habitat features is better understood, management measures can be better designed to maintain and potentially enhance fisheries productivity. Basic biology and life history information is lacking for many deep sea coral and sponge species. Understanding growth rates, reproduction, dispersal, and ages of deep sea corals and sponges will provide estimates of recovery time for different habitat types. In summary, the Oceana Approach includes research and mapping on coral and sponge ecosystems that is focused on where it is, what it does, what damages it, and how long it takes to grow back.

In the long term, an adaptive management approach will improve the cost effectiveness of management measures described thus far. Adaptive management is the concept that management measures should be designed using whatever data are available and improved over time by collecting data to address remaining policy questions and scientific uncertainties (see Holling 1978; Walters 1986). The monitoring and enforcement components described above can be used to identify areas where bycatch rates are highest within areas that remain open. Additionally, they may also reveal more spatially explicit information on which areas have more and less relative effort. These data should be used to develop additional closed areas based on areas of higher bycatch rates and areas that become not as important to the fishery. Research and mapping components may be used to identify coral and sponge gardens within open areas that should become closed. As enforcement and monitoring capabilities improve with technological innovations, the scale of management, or the size of the grid blocks, should decrease so that management can take place at a resolution that better fits the patchiness of the seafloor habitat types and the spatial resolution of fishing effort.

In addition, the research and mapping components can be designed to provide opportunity for re-opening areas previously closed. Criteria for opening areas could be that they have either been mapped or thoroughly observed in situ and do not contain sensitive habitats such as corals and sponges. When research identifies gear modifications that reduce impacts on habitats while still catching fish, these modifications can be incorporated into the management regime.

Expected results of implementing the Oceana Approach

NMFS (2004c) conducted significant analysis of Alternative 5B, which they developed based on the Oceana Approach described above. In addition, specific numerical statistics regarding the analysis were provided to the authors (J. Kurland, Director, NMFS Alaska Region Habitat Conservation Division, personal communication). While these numbers may change with additional analysis, they provide an example of the results that can be expected of a habitat protection policy formulated using the Oceana Approach.

Alternative 5B would reduce the impact of bottom trawling over 82,023 km^2 of Aleutian Island seafloor habitat or 77.9 percent of the current fishable area of 105,243 km^2 (NMFS 2004c). If implemented, Alternative 5B would significantly reduce coral and sponge bycatch in trawl fisheries in the Aleutian Islands. NMFS estimates that 36% of the historic coral bycatch and 24% of the historic sponge bycatch from 1990-2001 occurred in areas that would become closed to bottom trawling under this alternative (J. Kurland, Director, Habitat Division, NMFS Alaska Region, personal communication). Since these areas as well as previously untrawled areas would become closed, these values represent the minimum level of bycatch reduction can be expected if this alternative is implemented. Bycatch caps based on historical levels from remaining open areas will provide insurance that this mitigation will actually occur. NMFS (2004b) calculated that the TAC reductions based on the average percentage of catch that occurred in closed areas from 1998 to 2001 would be:

- 6.0% for the Atka mackerel trawl fishery,
- 10.0% for the Pacific cod trawl fishery, and
- 12.0% for the rockfish trawl fisheries.

Therefore, the scale of coral and sponge bycatch reduction accomplished through the Aleutian Islands model is roughly three-fold greater than the reductions in groundfish catch imposed on the bottom trawl industry. The above results confirm our hypothesis that it is possible to design cost effective habitat protection measures by taking advantage of the fact that bycatch rates are spatially heterogeneous. This shows that it is possible to substantially mitigate the adverse impacts of fishing on Essential Fish Habitat while maintaining vibrant fisheries, assuming all other things being equal. These results would be expected to further improve through the adaptive management strategy described above.

Discussion

The Oceana Approach effectively reduces adverse impacts of bottom trawling on EFH at minimum cost to the bottom trawl industry, but is only a first step. As mentioned, some areas known to contain corals and sponges remain open to bottom trawling under this approach. To maintain the full productive capacity of fish habitat, fishermen must continue to reduce the ecosystem impacts of harvesting fish. Several scientists and managers have commented that it may be more appropriate to consider total coral and sponge bycatch rather than bycatch rates. While this may afford substantial protection to deep sea coral and sponge ecosystems, this will necessitate a greater reduction in TAC than would be necessary for the same reduction in bycatch using a rate threshold.

This approach contrasts approaches that apply random closures or closures in areas of highest trawl effort, while leaving all remaining areas open. For random closures, such as strip closures across depth strata, it is most likely that the percentage of TAC reduction and bycatch reduction are roughly equivalent to the percentage of area closed. For closures in areas of high trawl effort, it is likely that the economic costs will be high with small habitat benefit and possibly increased habitat impacts in remaining open areas if fishing effort is not reduced.

In contrast to the status quo fishing regime in the Aleutian Islands, Alternative 5B embodies a more precautionary approach that errs on the side of conservation particularly with regard to rare species and habitat types. Due to the patchiness of deep sea coral and sponge habitats and the high species richness observed at many sites, these ecosystems likely contain rare or endemic species that may be found no where else in the world. The recent discovery of several new species and even a new genus of corals from recent submersible expeditions in the Aleutian Islands shows this is not merely postulation (R. Stone, personal communication). Many of these species may also produce valuable cures to human diseases, climate change data, and genetic information (Witherell and Coon 2000). There also may be unique assemblages of deep sea coral and sponge species resulting in rare habitat types yet to be discovered. Protecting these unexplored, untrawled sites ensures that these unique, undiscovered species and habitat types will exist for the benefit of future generations. With recovery times in the hundreds to thousands of years, damage to these habitats is for all practical purposes irreversible on a management time scale. Therefore, although the full value to society of protecting coral and sponge ecosystems is not yet understood, the option value of protecting these vulnerable ecosystems may be far greater than the short-term costs imposed on the industry. If a less precautionary approach is taken, such as the status quo, it is likely that many of these rare habitats and unique ecological linkages will be gone before they are discovered.

Successful implementation of the Oceana Approach requires an investment in better fisheries management. Enforcement must be able to enforce open and closed areas at a high level of spatial resolution. Observer coverage must increase and training must include identification of invertebrates. Managers and fishermen must use the latest technologies, including vessel monitoring systems, electronic logbooks, and state of the art sounders. Incentives must be enforceable and significant. Management must be flexible enough to incorporate new information to improve the various policy components. There must be a commitment to research and seafloor mapping to guide the adaptive management process. This investment will ensure that we have productive fisheries and healthy ocean ecosystems for generations to come.

The Oceana Approach is recommended for application to other regions and should be adjusted based on available fishery and biological data for each region. For example, thresholds selected for defining open areas should be selected relative to the data for each region, rather than a specific number. It is useful to view the results using different threshold values to compare the costs and benefits. The essence of this threshold rate approach is that it optimizes bycatch reduction subject to any chosen economic cost constraint. In other words, for any level of economic costs fishery managers are willing to impose on the trawl industry, it is possible to choose specific maximize the protection of deep sea coral ecosystems.

Management measures designed using the Oceana Approach will be most effective in regions with accurate spatial records of coral and sponge bycatch, but the approach can also be applied at a coarser scale based on any level of available data. For example, if observer data are not available, trawl survey data may be used to determine the relative ratio of coral and sponge concentration to target species catch per unit effort. The approach works best in areas where fishery locations are relatively static, but can be tailored to more dynamic fisheries by incorporating longer time series in the determination of open areas. The methodologies described above could also potentially be applied to any gear type that may have adverse impacts to EFH. It can also be applied to other habitat features that are vulnerable to fishing activities. To do this, it is necessary to determine which features of EFH are vulnerable to disturbance, and the extent to which each gear type affects these features.

If there is indeed a positive functional relationship between deep sea coral and sponge ecosystems and commercial fish populations as suggested by the documented species associations, it is clear that the adverse impacts from bottom trawling are continuing to reduce the productivity of their own fisheries as well as fisheries prosecuted with other gear types. In the end, a sustainable groundfish fishery in the Aleutian Islands will require developing new fishing techniques that effectively harvest the fish without destroying the habitat the fish need to survive, reproduce, and grow to maturity. Considering the current political strength of the trawl industry in Alaska's fishery management context, the only way to stop bottom trawling on corals, sponges and seamounts may be to simply buy out the capacity. As in other resource conflicts such as groundfish collapses on the U.S. west coast and New England, federal buyouts are often the inevitable results of unsustainable resource management. The paradox is that while there may be economic incentives encouraging bottom trawling in deep sea coral and sponge habitats, the irreversible consequences of this destructive activity will ultimately hurt the economy. A truly sustainable human existence on this planet requires that we actively develop new policy approaches and technologies that provide opportunities to maintain the economy and catch fish without destroying natural habitats and ecosystems.

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